# Model Assessment and Deployment Strategies for Drifting Instruments

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## LONG-TERM GOALS

This effort is closely linked with our effort on ONR grant N00014-05-1-0092 and is a component of the Optimal Deployment of Drifting Acoustic Sensors, ODDAS. We collaborate with A. C. Poje of CUNY SI; S. Riedlinger and R. Allard at NRL SSC; D. Hammond at Advanced Avionics; and D. Porter and R. Heitsenrether at APL/JHU. The long-term goal of ODDAS is to develop strategies for the deployment of drifting sensors that maximize the amount of environmental information collected with the fewest sensors. Two critical concerns in these deployments are: the advection of the array out of the region of interest during the operational period, and the distortion of the array with subsequent loss of information. Mesoscale and submesoscale advective processes are responsible for array translation and distortion. Our primary long-term research goal is to quantify submesoscale stirring process. Calculating the origin and fate of representative parcels is an essential part of our analysis. Thus, the long-term research and ODDAS goals are complementary. The methodology is directly applicable to deployment planning and the data from the deployments are useful in our assessments of stirring.

## OBJECTIVES

Two objectives were pursued during FY07:

- Post-analysis of LWAD-05 and LWAD-06 deployments and comparison with EAS16 model results.

- Assist in the planning for the LWAD-07 deployments.

## APPROACH

As documented in publications and previous progress reports, we have developed a variety of Lagrangian methods to quantify advective processes from synoptic velocity maps. We have applied these methods to both observed velocity fields obtained by HF radar, and model velocity archives. For the latter we focus on data-assimilating models. To date we have not used statistical methods to parameterize subgrid scale processes, so that our computed trajectories describe only simple advection of passive particles. These methods have provided new insight into submesoscale processes.

Our Lagrangian tools include the following:

*Inflowing/outflowing manifolds* – Using archived two-dimensional velocities and careful initialization of particles, precise curves that define manifolds can be numerically computed in both forward and backward time. In the vicinity of hyperbolic points (always associated with nearby stagnation points), these manifolds define flow boundaries where strong deformation occurs. Because of their fundamental importance, it is highly desirable to automate manifold computation. Regrettably, the numerical challenges associated with an automated code remain daunting.

*Gridded trajectories* – To quickly understand the Lagrangian character of a two-dimensional velocity archive, regular grids of particle initial positions can be used to compute both forward and backward time trajectories. Maps of these trajectories give an impression of the evolving flow field, and the trajectories can be used to compute quantities like relative dispersion.

*Relative dispersion* – Using gridded trajectories computed from a two-dimensional velocity archive, relative dispersion in both forward and backward time can be computed. Regions of strong dispersion are closely related to the more precise manifold structure in hyperbolic regions.

*Finite-scale Lyapunov exponents* – Either finite-time or finite-length Lyapunov exponents can be estimated for a two-dimensional velocity archive. These are closely related to relative dispersion, and are more straightforward to compute than manifolds. Lyapunov exponent maps give a synoptic picture of local deformation in the same way that relative dispersion maps do.

*Synoptic Lagrangian maps* – For a defined region of interest, gridded trajectories computed from a two-dimensional velocity archive can be used to compute Lagrangian characteristics at each point on a regular grid. Synoptic maps of Lagrangian properties summarize the particle behavior over an entire domain. Maps can be computed for either forward or backward time quantities. We compute synoptic maps of residence time, particle source, and particle fate.

## WORK COMPLETED

Tasks accomplished during this funding period include:

- Comparision of LWAD-05 deployment with the relative dispersion calculated from EAS16 model hindcasts.

- Comparision of LWAD-06 deployment with the relative dispersion calculated from EAS16 model hindcasts.

- Examination of the evolving sensor array boundary box and a preliminary assessment of the differences in the model and observed arrays, and assessment of metrics for assessing the differences.

- Evaluation of EAS16 model performance based on comparison with the observed dispersion of drifting sensors.

## RESULTS

Figure 1 summarizes much of the results. Figure 1 (a,c) shows the relative dispersion for the LWAD-05 and LWAD-06 deployments. The yellow boxes in each panel show the deployment sites. The red (blue) curves show the largest values of relative dispersion in forward (backward) time. These calculations are based on the EAS16 hindcast, which includes tides. Figure 1 (a ,c) shows that the strongest dispersion is confined to the Kurshio and the straits between Taiwan and the Philippines. Note that the strongest relative dispersion tends to line up in long filaments or strings. Along the core of the Kuroshio the forward and backward curves tend to be parallel, indicating that they are associated with jet structures. In local regions, which are not readily seen at this scale, the red and blue curves cross. The crossings are often found in regions of particularly weak currents, such as the region between eddies. Although the currents are weak in these regions, they are not particularly good sites for deployments of arrays of drifting sensors. The strong shears in these hyperbolic regions will quickly distort arrays, thus limiting their operational use.

Figure 1 (b,d) show trajectories initialized at each EAS16 grid point in the vicinity of the LWAD-05 and LWAD-06 deployments. The LWAD drifter tracks are shown in yellow with the starting and ending locations shown as black diamonds and red circles respectively. The LWAD-05 deployment (Figure 1a) was in a region of low dispersion. The agreement between the model and observed deployments is quite good. Both model and observed drifters moved to the north and both show the characteristic looping of tides. Moreover, the array maintained a high degree of coherence during the operational phased. The agreement of the tidal phases between the model and the deployment was a pleasant surprise.

The LWAD-06 drifters were launched inside the Kuroshio, as shown by the yellow box in Figure 1c. Note the strong deformation running through the deployment site. Not suprisingly, the agreement model and observed trajectories diverged much more rapidly than the LWAD-05 drifters, as seen in Figure 1d. The LWAD-06 array quickly lost coherence. The northwest portion moved to the northwest while the northeast portion moved northeast. In addition, the agreement between distortion of the model and observed drifter arrays was poor. However, both the observed and modeled trajectories showed good agreement with tidal phases.

Not shown here is the comparison of the LWAD-06 observed trajectories with the dispersion curves from EAS16. The model relative dispersion maps show coherent features that fluctuate slowly with the tides. Preliminary analysis suggests that they provide a reasonable template for the array movement and distortion in a region such as this, where there is substantial shear. The conclusion from this exercise is that the EAS16 model cannot reliably predict individual trajectories, but it demonstrates skill in predicitng the evolution of coherent Lagrangian features that are important in array planning.

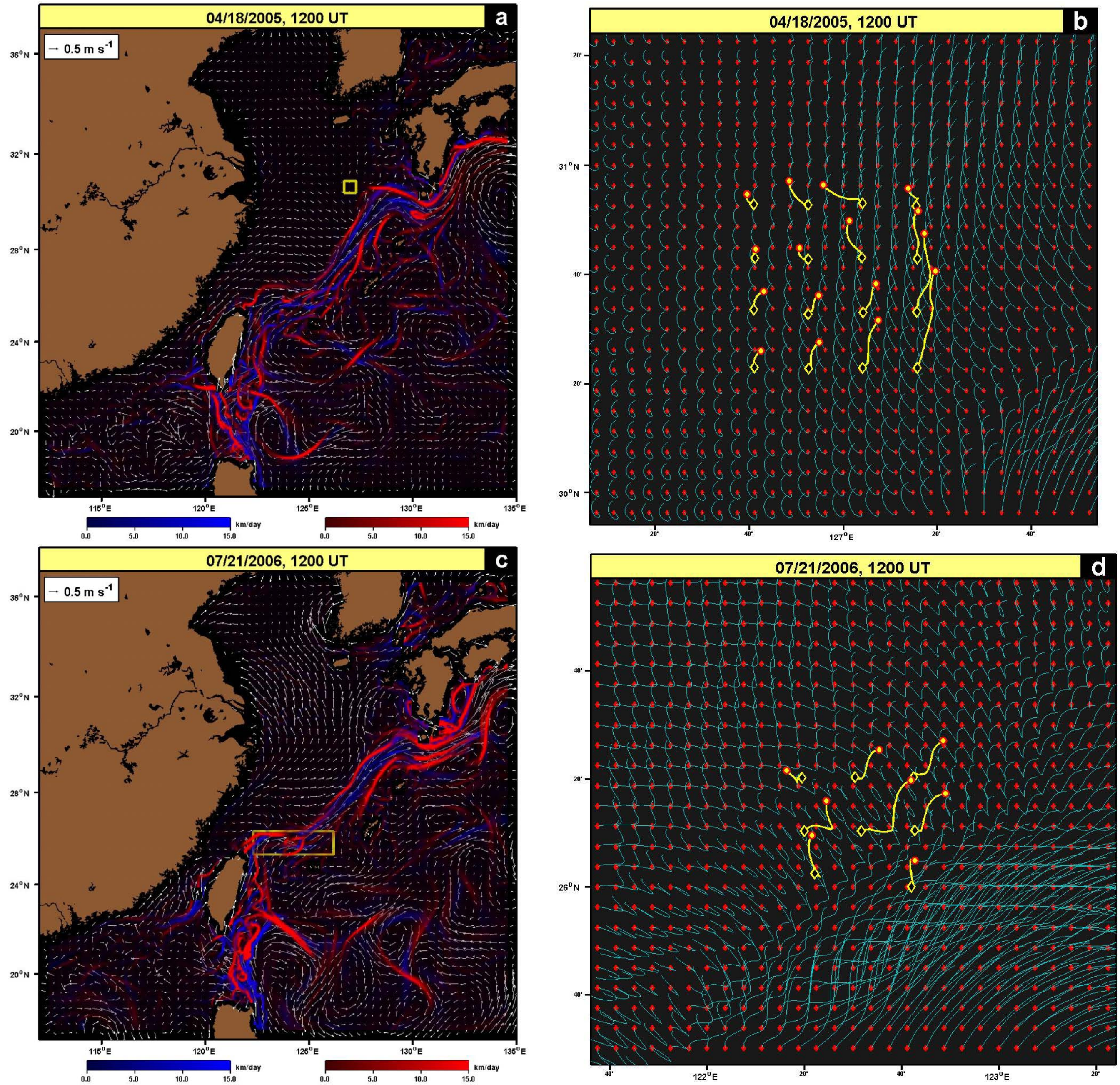


***Figure 1: Relative dispersion (a,c) and gridded trajectories (b,d) computed from EAS16 model velocities at 10m at the time of GPS drifter launch for the LWAD-05 (a,b) and LWAD-06 (c,d) experiments. The drifter launch boxes are shown in yellow in (a,c) In (b,d) the drifter launch positions (black diamonds), positions after twelve hours (yellow circles) and the trajectories over the first twelve hours (yellow) are shown, and twelve hour trajectories for each EAS16 model grid point (grid points in red) are shown in light blue.***

## IMPACT/APPLICATIONS

During FY07, we have had some success in applying Lagrangian methods to the post analysis of LWAD deployments. We have developed close working relationships with personnel at NRL, APL/JHU, and Advanced Avionics who also are working on ODDAS. It is now clear that several groups within the Navy Establishment need Lagrangian type information for their operations. It is satisfying that the rather abstract methods we have developed may have some practical application. From the scientific perspective, the more important issue is that the applications to deployments have spurred additional lines of basic research.

**RELATED PROJECTS**

This grant is closely connected with ONR grant N00014-05-1-0092. Most of the analysis methods used here are also used on the latter grant. The PI and CO-PI of the present grant are also the principals on the latter grant.

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